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AIR EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM A NATURAL GAS FIRED ENGINE

Prepared for:

CORE ENERGY, LLC
CHESTER 10 CPF FACILITY
SRN N5798

ICT Project No.: 2200207
February 13, 2023

IMPACT COMPLIANCE & TESTING

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Report Certification

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
NATURAL GAS FIRED ENGINE

Core Energy, LLC – Chester 10 CPF Facility
Chester Township, MI

Report Certification

The material and data in this document were prepared under the supervision and direction of the undersigned.

Impact Compliance & Testing, Inc.

Tyler J. Wilson
Senior Project Manager

I certify that the facility and emission unit was operated at maximum routine operating conditions for the test event. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Responsible Official Certification:

Brian Dorr
Chief Operating Officer
Core Energy, LLC

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1.0 Introduction

Core Energy, LLC (Core Energy) operates natural gas-fired reciprocating internal combustion engines (RICE) at the Chester 10 CPF Facility in Chester Township, Otsego County, Michigan. The RICE are fueled by natural gas and are used to provide mechanical power to operate gas compressors. The facility compresses carbon dioxide gas prior to injecting it into oil wells.

The State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) has issued Permit to Install (PTI) No. 579-95F to the Core Energy Chester 10 CPF Facility, which generally consists of:

- Two (2) Caterpillar (CAT®) Model No. G3608 RICE identified as emission units EUENGINE1 and EUENGINE2 (Flexible group ID FGENGINES).
- One (1) CAT® Model No. G3612 RICE identified as emission unit EUENGINE3 (Flexible Group ID FGENGINES).

Air emission compliance testing was performed pursuant PTI No. 579-95F and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ). Conditions of PTI No. 579-95F for EUENGINE3 state:

> *Unless EUENGINE3 is a certified engine according to procedures specified in 40 CFR Part 60 Subpart JJJJ, and is maintained and operated as such, the permittee shall conduct performance testing every 8,760 hours of operation or three years from the previous performance test, whichever comes first, for EUENGINE3 to verify compliance with the emission limits in SC I.4, SC I.8, and SC I.9.*

The compliance testing was performed by Impact Compliance & Testing, Inc. (ICT), a Michigan-based environmental consulting and testing company. ICT representatives Tyler Wilson and Nick Steinthal performed the field sampling February 7, 2023.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons (NMHC or NMOC)). Exhaust gas velocity, moisture, oxygen (O_2) content, and carbon dioxide (CO_2) content were determined for each test period to calculate pollutant mass emission rates.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated December 30, 2022, that was reviewed and approved by EGLE-AQD.

Questions regarding this air emission test report should be directed to:

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2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

Conditions of PTI No. 579-95F and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines require Core Energy to test EUENGINE3 for CO, NOx, and VOC emissions. Engine No. 3 (EUENGINE3) was tested during this compliance test event.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while EUENGINE3 operated at maximum routine operating conditions.

Fuel flowrate (scfm), engine shaft rotation (rpm), catalyst inlet temperature (°F), and engine load (%) were recorded by Core Energy representatives at 15-minute intervals for each test period.

Appendix 2 provides operating records provided by Core Energy representatives for the test periods.

Engine output (brake-horsepower, bhp) cannot be measured directly and was calculated based on the recorded engine shaft rotation (rpm). Core Energy provided engine spec sheets that list the horsepower produced and engine shaft rotation (rpm) at maximum load. To determine the horsepower output at a lower load the following equation was used:

Engine Output (bhp-hr) = Max Output (bhp-hr) * Measured rotation (rpm) / Max rotation (rpm)

Average engine operating conditions for EUENGINE3 are presented in Tables 2.1 and 6.1.

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the RICE (EUENGINE3) were sampled for three (3) one-hour test periods during the compliance testing performed February 7, 2023.

Table 2.2 presents the average measured emission rates for EUENGINE3 (average of the three test periods).

Test results for each one-hour sampling period and comparison to the permitted emission rates is presented in Section 6.0 of this report.

Table 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE3 CAT® G3612
Engine rotation (RPM)	829
Calculated engine output (bhp)	2,944
Engine load (%)	95
Engine fuel use (scfm)	314
Catalyst inlet temperature (°F)	744

Table 2.2 Average measured emission rates for Engine No. 3 (three-test average)

Emission Unit	CO		NOx		VOC
	(tpy*)	(g/bhp-hr)	(tpy*)	(g/bhp-hr)	(g/bhp-hr)
EUENGINE3	14.3	0.50	7.03	0.25	0.53
Permit Limit	***17.13***	***2.0***	***11.88***	***1.0***	***0.7***

*Note: Tons per year is based on 8,760 hours per year operation.

3.0 Source and Sampling Location Description

3.1 General Process Description

Core Energy operates a gas compressor station at the Chester 10 CPF facility. Natural gas, which has been recovered from nearby wells, has the carbon dioxide removed at an adjacent facility. The carbon dioxide gas stream is routed to the Core Energy Chester 10 CPF Facility containing three (3) natural gas fired RICE that power gas compressors. The compressed carbon dioxide gas stream is injected into an oil reservoir.

3.2 Rated Capacities and Air Emission Controls

The Core Energy CAT® Model No. G3612 RICE (Engine No. 3 / EUENGINE3) has a rated output of 3,071 bhp at 865 rpm (3,550 bhp at 1,000 rpm).

The RICE and connected gas compressor is a continuous-type process. The engine is operated at the load (percent output) needed to drive the gas compressor to provide the desired volumetric flow and compression ratio for the transport and injection of carbon dioxide. The engine is equipped with an air-to-fuel ratio controller (AFRC) that manages the fuel flow and combustion air flowrates based on the engine load.

EUENGINE3 is equipped with a catalyst emission control system to reduce emissions. CO and hydrocarbons in the RICE exhaust gas stream are oxidized by the catalyst using excess oxygen that is present in the RICE exhaust gas stream. The RICE exhaust gas provides the heat necessary to initiate the catalytic reaction (an additional heat source is not used to preheat the engine exhaust gas). The temperature at the catalyst inlet is monitored continuously to verify that RICE exhaust gas temperature / catalyst inlet temperature is within the proper range for the catalytic reaction.

3.3 Sampling Locations

After the oxidation catalyst, the RICE exhaust gas is directed through a vertical noise muffler and is released to the atmosphere through a dedicated vertical exhaust stack.

The engine exhaust sampling ports for EUENGINE3 are located in the vertical exhaust stack that has an inner diameter of 26.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 180 inches (6.9 duct diameters) upstream and 63.0 inches (2.4 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

All sample port locations satisfy the USEPA Method 1 criteria for a representative sample location. Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides a diagram of the emission test sampling locations with actual stack dimension measurements.

4.0 Sampling and Analytical Procedures

A Stack Test Protocol for the air emission testing was reviewed and approved by EGLE-AQD. This section provides a summary of the sampling and analytical procedures that were used during the testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 7E	Exhaust gas NOx concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using an infrared instrumental analyzer.
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with methane separation column.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once during each test period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked periodically throughout the test event to verify the integrity of the measurement system.

The absence of significant cyclonic flow at the sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO_2 and O_2 content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a Servomex 1440D infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 1440D gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the RICE exhaust gas stream was extracted from the stack using a stainless-steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 Exhaust Gas Moisture Determination (USEPA Method 4)

Moisture content of the RICE exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. Exhaust gas moisture content measurements were performed concurrently with the instrumental analyzer sampling periods. At the conclusion of each sampling period the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

Appendix 3 provides moisture calculations and field data sheets.

4.5 NO_x and CO Concentration Measurements (USEPA Methods 7E and 10)

NO_X and CO pollutant concentrations in the RICE exhaust gas stream were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_X analyzer and a TEI Model 48i infrared CO analyzer.

Throughout each test period, a continuous sample of the engine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix 4 provides CO and NO_X calculation sheets. Raw instrument response data are provided in Appendix 5.

4.6 Measurement of Volatile Organic Compounds (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC or NMOC) concentration in the engine exhaust gas. NMHC pollutant concentration was determined using a TEI Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components. The concentration of NMHC in the sampled gas stream, after separation from methane, is determined relative to a propane standard using a flame ionization detector in accordance with USEPA Method 25A.

The USEPA Office of Air Quality Planning and Standards (OAQPS) has issued an alternate test method approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled RICE (ALT-096).

Samples of the exhaust gas were delivered directly to the instrumental analyzer using the Teflon® heated sample line to prevent condensation. The sample to the NHMC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis).

Prior to, and at the conclusion of each test, the instrument was calibrated using mid-range calibration (propane) and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document).

Appendix 4 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 5.

5.0 QA/QC Activities

5.1 Flow Measurement Equipment

Prior to arriving onsite (or onsite prior to beginning compliance testing), the instruments used during the source test to measure exhaust gas properties and velocity (pyrometer, Pitot tube, and scale) were calibrated to specifications in the sampling methods.

5.2 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO_x concentration is at least 90% of the expected value (within 10%).

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_X concentration was 100.3% of the expected value).

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_X, CO, O_2, and CO_2 have had an interference response test preformed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NO_x, CO, CO_2, and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless-steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

At the beginning of each test day, appropriate high-range, mid-range, and low-range span gases followed by a zero gas were introduced to the NMHC analyzer, in series at a tee connection, which is installed between the sample probe and the particulate filter, through a poppet check valve. After each one-hour test period, mid-range and zero gases were re-introduced in series at the tee connection in the sampling system to check against the method's performance specifications for calibration drift and zero drift error.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The NMHC (VOC) instrument was calibrated with USEPA Protocol 1 certified concentrations of propane in air and zeroed using hydrocarbon-free air. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for the RICE exhaust stack. The stainless-steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid), and 83.3% of the stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data for the RICE exhaust stack indicated that the measured NOx, O_2, and CO_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.7 System Response Time

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

Sampling periods did not commence until the sampling probe had been in place for at least twice the greatest system response time.

5.8 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 6 presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas certifications, interference test results, meter box calibration records, and field equipment calibration records).

6.0 Results

6.1 Test Results and Allowable Emission Limits

Engine operating data and air pollutant emission measurement results for each one-hour test period are presented in Table 6.1.

Engine No. 3 / EUENGINE3 has the following allowable emission limits specified in PTI No. 579-95F:

- 2.0 grams per brake-horsepower hour (g/bhp-hr) and 17.13 tons per year (tpy) for CO;
- 1.0 g/bhp-hr and 11.88 tpy for NOx;
- 0.7 g/bhp-hr for VOC.

The measured air pollutant concentrations and emission rates for Engine No. 3 / EUENGINE3 are less than (in compliance with) the allowable limits specified in PTI No. 579-95F.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

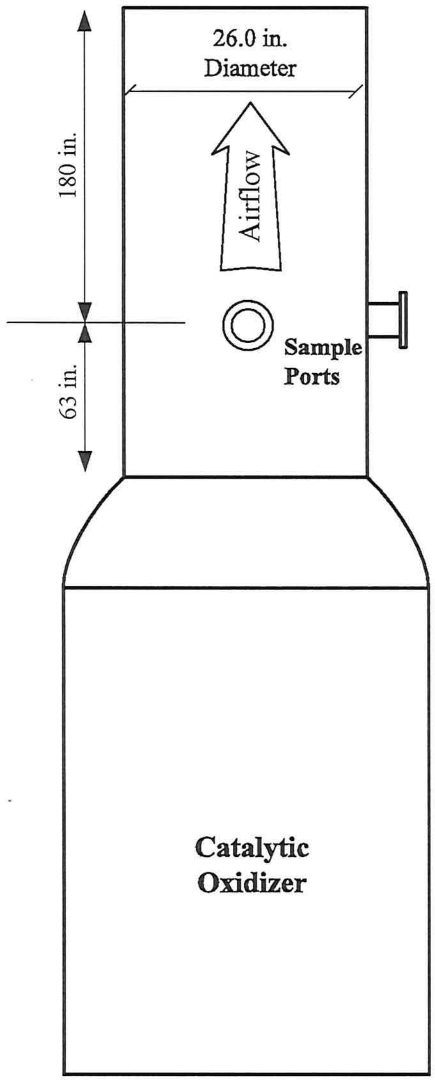
The testing for all pollutants was performed in accordance with USEPA methods and the approved Stack Test Protocol. The RICE was operated at maximum routine operating conditions throughout the compliance testing and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EUENGINE3)

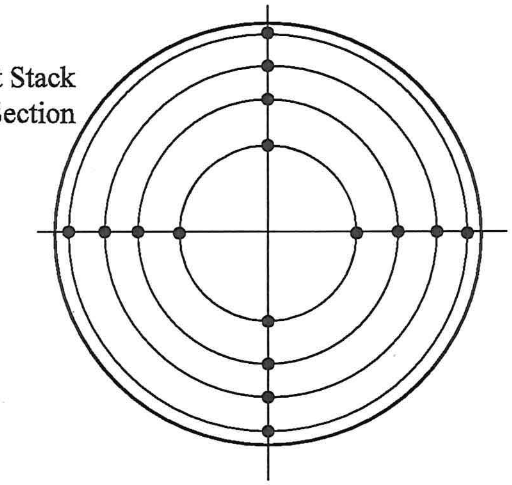
Test No. Test date Test period (24-hr clock)	1 2/7/2023 0816-0916	2 2/7/2023 0935-1035	3 2/7/2023 1055-1155	Three Test Average
Engine rotation (RPM)	830	827	831	829
Calculated engine output (bhp)	2,947	2,936	2,949	2,944
Engine load (%)	94	95	96	95
Engine fuel use (scfm)	312	315	315	314
Catalyst inlet temperature (°F)	744	745	743	744
Exhaust Gas Composition				
CO_2 content (% vol)	5.10	5.11	5.14	5.12
O_2 content (% vol)	12.4	12.4	12.4	12.4
Moisture (% vol)	8.7	8.7	9.7	9.0
Exhaust gas temperature (°F)	644	647	645	645
Exhaust gas flowrate (dscfm)	6,809	6,799	6,892	6,833
Exhaust gas flowrate (scfm)	7,458	7,450	7,631	7,513
Nitrogen Oxides				
NO_X conc. (ppmvd)	34.6	32.4	31.2	32.7
NO_X emissions (lb/hr)	1.69	1.58	1.54	1.60
NO_X emissions (tpy)	7.40	6.92	6.76	7.03
Permit Limit (tpy)	-	-	-	*11.88*
NO_X emissions (g/bhp-hr)	0.26	0.24	0.24	0.25
Permit Limit (g/bhp-hr)	-	-	-	*1.0*
Carbon Monoxide				
CO conc. (ppmvd)	108	110	111	110
CO emissions (lb/hr)	3.22	3.26	3.34	3.27
CO emissions (tpy)	14.1	14.3	14.6	14.3
Permit Limit (tpy)	-	-	-	*17.13*
CO emissions (g/bhp-hr)	0.50	0.50	0.51	0.50
Permit Limit (g/bhp-hr)	-	-	-	2.0
Volatile Organic Compounds				
VOC conc. (ppmv as C_3)	66.8	67.1	65.6	66.5
VOC emissions (lb/hr)	3.42	3.44	3.44	3.43
VOC emissions (g/bhp-hr)	0.53	0.53	0.53	0.53
Permit Limit (g/bhp-hr)	-	-	-	*0.7*

APPENDIX 1

- RICE Engine Sample Port Diagram



Exhaust Stack
Cross-Section



Velocity sample locations as measured from stack wall (not including 1.25" sample port)

Pt. #	in.
1	0.83
2	2.73
3	5.04
4	8.37
5	17.6
6	21.0
7	23.3
8	25.2

7/18/2017 ALR	**Attachment 1 – Core Energy, LLC** **Engine No. 3 Sampling Location**		
	Scale None	Sheet 1 of 1	IMPACT COMPLIANCE & TESTING